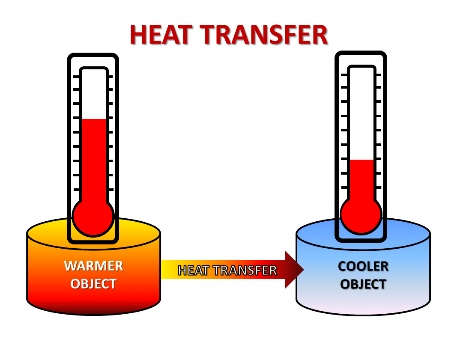
**Chapter 5 – THERMOCHEMISTRY**

**CHANGES IN MATTER AND ENERGY**

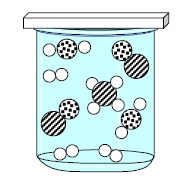
* *Thermochemistry:* the study of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ involved in chemical and physical processes
* *Temperature:* \_\_\_\_\_\_\_\_\_\_\_\_\_ kinetic energy of the particles in a sample of matter. It tells us how fast the particles in a substance, on average are moving

There are 3 ways that particles can move (that is, there are three types of molecular motion)

|  |  |  |
| --- | --- | --- |
| **V\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**    The movement of the atoms along the bonds in a molecule | **R\_\_\_\_\_\_\_\_\_\_\_\_\_\_**    When an atom or molecule spins on its axis | **T\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**    When a molecule moves from one place to another |

* *Thermal energy:* the sum of all the kinetic energies of all (moving) particles of a sample of matter.
* The more particles there are (moles), the \_\_\_\_\_\_\_\_\_\_\_\_\_\_ the thermal energy
* The faster the particles are moving, the \_\_\_\_\_\_\_\_\_\_\_\_\_\_ the thermal energy
* *Heat (q):* amount of \_\_\_\_\_\_\_\_\_\_ transferred between substances, it is always transferred from the substance with \_\_\_\_\_\_\_\_\_\_ temperature to the substance with \_\_\_\_\_\_\_\_\_ temperature (2nd law of thermodynamics)

Symbol = q Unit = J or kJ (1 kJ = 1000 J)

A **system** refers to all of the chemical components that are involved in a chemical reaction- the reactants, products and whatever solvents they are in (air, water etc). Everything outside of the system we are studying is called the **surroundings**.

Universe = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

* *Open System:* a system that can exchange both energy and matter with its surrounding
* *Closed System:* a system that can exchange energy, but not matter, with its surrounding
* *Isolated System:* a system that cannot exchange energy or matter, with its surrounding



An \_\_\_\_\_\_\_\_\_\_\_system A \_\_\_\_\_\_\_\_\_\_ system An \_\_\_\_\_\_\_\_\_\_ system

<http://youtu.be/5Yq5nWFotxw> <http://youtu.be/G1UR-hrAB-g> <http://youtu.be/aNXKGgQOpdk>

**What’s the difference between thermal energy, temperature and heat?**

Analogy: Think about cars travelling on the 401.

* Each car = a single molecule.
* the cars are translating (moving from one place to another)
* all of the cars are moving at different speeds. The average speed of all of the cars represents ***temperature***.
* If there are a lot of cars on the 401, even if they are moving slowly, there will be a lot of total movement. The total amount of movement represents ***thermal energy***.
* The more cars there are and the faster they are moving, the greater the thermal energy (or total movement).
* if a fast-moving car hits a slow-moving car, it will make the slower car speed up.
* Some of the kinetic energy of the fast car is transferred to the slow car. This represents ***heat*** (energy transfer).
* if the cars are not moving and have their engines turned off- they have no kinetic energy. This

represents absolute zero.

**Practice Problems**

1. What is the difference between thermal energy and temperature of a substance?
2. Classify each of the following as an open system or a closed system
3. a pot of boiling water d) a sealed bottle of water
4. a helium balloon d) a hot-air balloon
5. the Earth
6. An isolated system has an initial temperature of 30oC. It is then placed on top of a Bunsen burner for an hour. What is the final temperature?

**Nature of energy & Heat, Specific Heat Capacity**

|  |  |  |  |
| --- | --- | --- | --- |
| Thermal energy of a system | Temperature | Heat | Specific heat capacity **c** |
| = sum of all kinetic energies of all particles of the system   * \_\_\_\_\_\_\_\_\_\_ be measured | Average kinetic energy of all of the particles of a system   * \_\_\_\_\_\_\_\_ be measured | =energy that flowed into or left the system can be calculated if the temperature of a system is measured before and after a reaction has occurred | Amt of energy that required to increase \_\_\_g of a substance by \_\_\_ oC   * Must be \_\_\_\_\_\_\_\_\_   experimentally   * **c** depends on state of the substance * values reported for standard ambient temp. & pressure (or SATP) which are 25oC & 100kPa (i.e. kilopascal) |

**Measurable and Calculated Variables of a System**

**Heat symbol, sign and meaning:** Heat symbol: q

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| When heat is | Sign of q | Direction of heat flow | Nature of process | Energy diagram |
| \_\_\_\_\_\_\_\_\_\_\_ by system  (or \_\_\_\_\_\_\_\_\_\_\_\_ to the system) | q is \_\_\_\_ | from \_\_\_\_\_\_\_\_\_ to \_\_\_\_\_\_\_\_\_ | E\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  e.g. |  |
| \_\_\_\_\_\_\_\_\_\_\_ by system  (or \_\_\_\_\_\_\_\_\_\_\_\_ from the system) | q is \_\_\_\_ | from \_\_\_\_\_\_\_\_\_ to \_\_\_\_\_\_\_\_\_ | E\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  e.g. |  |

**First law of thermodynamics**: Energy is \_\_\_\_\_\_\_\_\_\_\_\_\_\_

Because energy is always conserved, q system = - q surroundings

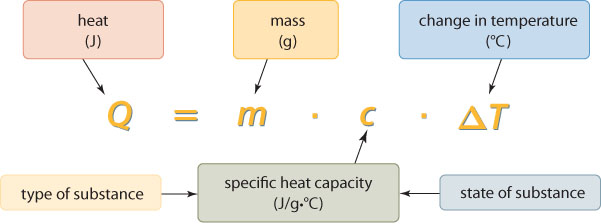
same as Δ Esystem = **-** Δ Esurroundings

**Second law of thermodynamics**:

When two objects are in thermal contact, heat will flow from the \_\_\_\_\_\_\_\_\_\_\_ to \_\_\_\_\_\_\_\_\_\_ object.

**CALORIMETRY- Measuring Energy Changes**

If the temperature of a system is measured **BEFORE** and **AFTER** a reaction has occurred, the energy that flowed into or left the system can be calculated using the following equation:



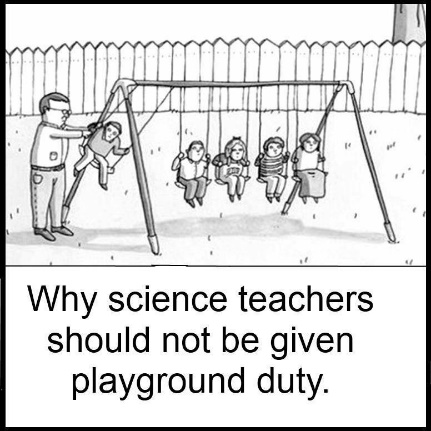
|  |  |  |  |
| --- | --- | --- | --- |
| When Tfinal >T initial: | Δ T\_\_\_\_\_\_\_\_\_ | Q \_\_\_\_\_\_\_\_\_ | Heat \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ system |
| When Tfinal <T initial: | Δ T\_\_\_\_\_\_\_\_\_ | Q \_\_\_\_\_\_\_\_\_ | Heat \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ system |

Every substance has its own characteristic specific heat capacity, a physical property of that substance. For example:

|  |
| --- |
| **Pure gold**: c = 0.129 J/gºC, which is very low   * one gram of pure gold requires 0.129 J of energy to make 1 g of its atoms move 1ºC faster. The specific heat capacity of gold is low for two reasons: * one gram of gold is not very many atoms ( MM of gold is 197 g/mol) * the metallic bonding holding the atoms of gold together is quite “fluid” so it doesn’t take much energy to get the gold atoms moving |
| **Pure aluminum**: c = 0.900 J/gºC, which is moderate   * one gram of pure aluminum requires 0.900 J of energy to make 1 g of its atoms move 1ºC faster. The specific heat capacity of aluminum is higher than for gold because: * there are 8x more aluminum atoms in one gram of aluminum than there are in one gram of gold (molar mass of aluminum is 27 g/mol) * aluminum has 3 valence electrons to participate in metallic bonding, so the forces of attraction between atoms is quite strong, so it takes more energy to get the aluminum atoms moving |
| **Pure water**: c = 4.184 J/g ºC, which is extremely high   * one gram of liquid water requires 4.18 J of energy to make 1 g of its molecules move 1ºC faster. The specific heat of water is high for two reasons: * one gram of water contains a lot of molecules because water molecules are very light (Molar mass = 18 g/mol) * there are very strong forces of inter-molecular attraction between water molecules because of the strong polarity of the molecule and hydrogen bonding, so it takes a lot of energy to get water molecules moving * another way of looking at this is that water has the ability to absorb a lot of energy with only a very small increase in temperature (which is what makes life on Earth possible) |

**CALORIMETRY PRACTICE PROBLEMS:**

1. If the same amount of heat were added to individual 1g samples of water, gold and aluminum, which substance would undergo the greatest temperature change? Explain
2. How much heat is needed to warm 25.5g of water from 14°C to 22.5°C? Is the reaction exothermic or endothermic?
3. How much heat would be needed to warm 250.0g of gold from 25°C to 100°C?
4. What is the temperature change if 1.386kJ is absorbed by 60.0g of copper?
5. An insulated cup contains 75g of water at 24.0°C. A 26.0g sample of metal at 82.25°C is added. The final temperature of water and metal is 28.34°C. What is the specific heat of the metal?
6. If 1.5kg of mercury loses 3.50kJ of heat, how much does the temperature drop? If the original temperature was 90.0°C, what is the final temperature?
7. If 0.05 kg of ethanol gains 1050 J of energy, the specific heat capacity of ethanol is 2.46J/g°C, if the final temperature of the sample is 24°C, what was its initial temperature?
8. A solid substance has a mass of 0.250kg. It is cooled by 25.0°C and loses 4937.50 J of energy. What is its specific heat capacity? What is the substance?
9. A sample of water is heated from 10.0°C to 50.0°C. During the process, 12.0kJ of heat are added to the water
10. What mass of water is heated?
11. How many moles of water are heated?



**Answers**

1. 906J 6. 73°C
2. 2.4kJ 7. 15°C
3. 60.0°C 8. 0.790 J/g°C
4. 0.971J/g°C 9. 71.8g, 3.99mol

**Compare the thermal energy and temperature of the following** (not to scale)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| System | A large iced coffee  https://s-media-cache-ak0.pinimg.com/236x/ba/b3/70/bab3702115d91f8cec0f6f798b54d008.jpg  500 grams | A small coffee  http://www.latestfreesamplescanada.com/8888/uploads/2013/10/M-Tim-Hortons-Contest.png  200 grams | A large coffee  http://www.latestfreesamplescanada.com/8888/uploads/2013/10/M-Tim-Hortons-Contest.png  500 grams | A bathtub full of water  http://images.wisegeek.com/white-clawfoot-bathtub.jpg  300,000 grams |
| Temperature | 0°C | 85°C | 85°C | 25°C |
| Rank the speed of the particles in these systems |  |  |  |  |
| Rank the Total Thermal Energy in these systems |  |  |  |  |